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PRODUCTIVITY AND NEST-SITE CHARACTERISTICS OF GRAY HAWKS IN SOUTHERN ARIZONA

BRENT D. BIBLES[1] AND R. WILLIAM MANNAN
School of Renewable Natural Resources, University of Arizona, Tucson, AZ 85721 U.S.A.

ABSTRACT.—We studied Gray Hawks (*Asturina nitida*) nesting along the upper San Pedro River in southeastern Arizona from 1995–97. We identified 27 nesting areas with a mean of 24.3 nesting areas occupied per year. Productivity averaged 1.32 young per occupied nest. Number of successful nests and number of young produced per nest did not differ among years. Mean size of home range (N = 10 males), based on the 90% adaptive kernel method, was 59.2 ha (range = 21.4–91.2). Almost all Gray Hawk nests were located in large, dominant cottonwood trees (*Populus fremontii*). However, we doubt that Gray Hawks inherently prefer cottonwood trees over other species, but rather speculate that they use them because they are the only tall nest substrate currently available. The increase in Gray Hawks in southern Arizona during the past 30 yr was probably due to an increase in habitat. In the future, groundwater depletion may represent a risk to maintenance of Gray Hawk populations in southern Arizona.

KEY WORDS: *Gray Hawk*; Asturina nitida; *Arizona*; *home range*; *productivity*; *nest characteristics.*

PRODUCTIVIDAD Y CARACTERÍSTICAS DEL SITIO DEL NIDO DEL GAVILAN GRIS EN EL SUR DE ARIZONA

RESUMEN.—Estudiamos el gavilán gris (*Asturina nítida*) anidando a lo largo de la cuenca alta del Rió San Pedro en el sureste de Arizona desde 1995–97. Identificamos 27 areas de anidacion con una media de 24.3 areas de anidacion ocupadas por año. La productividad promedio fue de 1.32 juveniles por nido ocupado. El numero de juveniles producidos por nido no difirió entre años. El tamaño de la media del rango de hogar (N = 10 machos), con base en el 90% del método adaptativo de kernel, fue de 59.2 ha (rango = 21.4–91.2). Casi todos las nidos del gavilán gris estaban ubicados en grandes y dominantes árboles de álamo (*Populus fremontii*). Sinembargo dudamos que el gavilán gris inherentemente prefiera los álamos a otra especie y especulamos que ellos los usan debido a que es el único árbol de gran porte dentro del substrato disponible. El aumento de gavilán gris en el sur de Arizona durante los pasados 30 años probablemente se de debe al aumento de hábitat adecuado. En el futuro, el agotamiento de las aguas subterráneas puede representar un riesgo para la sobrevivencia de las poblaciones del gavilán gris en el sur de Arizona.

[Traducción de César Márquez]

There is little quantitative information on the behavior, habitat use, or productivity of Gray Hawks (*Asturina nitida*) during the breeding season. Glinski and Millsap (1987) and Glinski (1988) provide the only data on productivity of Gray Hawks in Arizona. Nesting habitat has not been quantified except for narrative descriptions of individual nest sites (Glinski 1988), and there is no information on home-range size or habitat use. However, Gray Hawks in Arizona are known to occupy riparian woodlands of mesquite (*Prosopis juliflora*) and hackberry (*Celtis reticulata*) that are adjacent to stands of cottonwood (*Populus fremontii*) and willow (*Salix gooddingi*; Glinski 1988).

Currently, about 80 breeding pairs of Gray Hawks occur within the watersheds of the Santa Cruz and San Pedro rivers in southern Arizona (Glinski 1998). Cottonwood-willow and mesquite account for almost 93% of the riparian vegetation along these rivers (Hunter et al. 1987). Gray Hawks have recently increased in number within Arizona, probably due to an increase in habitat resulting from landscape changes that occurred over the past century (Glinski 1998). Effective management of Gray Hawk habitat requires knowledge of basic life history information. Therefore, we examined productivity, characteristics of nest sites and home ranges, and habitat use of Gray Hawks in Arizona.

[1] Present address: Colorado Division of Wildlife, 317 West Prospect Road, Fort Collins, CO 80526 U.S.A; e-mail address: brent.bibles@state.co.us

STUDY AREA

We studied Gray Hawks breeding along the San Pedro River in southeastern Arizona from 1995–97. The boundaries of the San Pedro Riparian National Conservation Area (SPRNCA), administered by the Bureau of Land Management, defined our study area. The SPRNCA encompasses about 23 500 ha along 64 km of perennial and intermittent river at elevations ranging from 1125–1280 m.

METHODS

We conducted fieldwork from early April–July of each year. We located nests of Gray Hawks by intensively searching cottonwood forests along the river early in the breeding season. Gray Hawk nests are relatively easy to locate because the hawks are vocal prior to incubation, and give alarm calls when humans enter the nest area. After a vocal pair was located, we searched all large trees nearby for nest structures. We considered a site occupied if a pair was present in the area performing behaviors consistent with nesting activities (e.g., vocalizations), regardless of whether a nest was located. We revisited occupied sites at least four times throughout the breeding season to determine productivity. A nest was considered successful if nestlings were observed within 2 wk of the normal fledging age of 42 d (i.e., >28-d-old; Glinski 1988). We climbed the nest tree, usually ≤2 wk before the nestlings fledged, to determine the number of young produced. We counted and determined the gender of nestlings based on diameter of the tarsus (Hull and Bloom 2001), and fitted them with U.S. Geological Survey bands. If we could not safely climb a nest tree, we counted nestlings from the ground. At least two visits were made to these nests during the late-nestling stage to confirm counts.

Each year, we determined the number of sites at which nesting was attempted, the number of sites that produced young successfully (i.e., young within 2 wk of fledging age), and the number of young produced at each site. We used the log-likelihood chi-square test (Sokal and Rohlf 1981) to compare the number of successful nests among years, and the Kruskal-Wallis test to compare the number of young produced among years (Gibbons 1985).

We followed radio-tagged, breeding, male Gray Hawks to develop home-range estimates. We used a dho-gaza set, with a live Great Horned Owl (*Bubo virginianus*) as a lure (Bloom 1987), to capture hawks. We attempted to capture hawks at sites representing all sections of the study area. We used epoxy and dental floss to attach radiotransmitters (Holohil Systems PD-2 transmitters, Carp, Ontario, Canada) to the central rectrix that exhibited the least wear (Dunstan 1973). Transmitters weighed 3.8 g, <1% of the mass of adult males.

We followed radio-tagged males ca. weekly during 4–8 hr sessions with the aid of a Telonics TR-4 receiver and RA-14 "H" antenna (Telonics, Mesa, AZ). We terminated observation sessions if it appeared that the hawk was changing its behavior as the result of our activities. We used homing (White and Garrott 1990) to relocate birds at hourly intervals during each session. We mapped locations of trees upon which hawks were perched on transparent overlays of aerial photos. We only used locations when we had a high degree of confidence that the bird was within 30 m of the mapped location. This level of accuracy was determined by visual or auditory confirmation of the bird's location, or by partially circling the location and noting the change in direction of the radio signal.

We used a geographic information system (Arc/Info and ArcView 3.1, Environmental Systems Research Institute, Inc., Redlands, CA) to obtain coordinates of bird locations. We digitally scanned the aerial photos used for field mapping and registered the scanned images to existing digital maps of the study area. We then digitized hawk locations using the digital photos as a reference. We used the 90% adaptive kernel (AK) and minimum convex polygon (MCP) methods (RANGES V, Institute for Terrestrial Ecology, London, U.K.) to calculate boundaries of home ranges. We calculated AK home ranges using a 40 × 40-m grid, and applied a smoothing factor determined by least squares cross validation. We calculated home ranges only when we obtained ≥30 observations on a hawk (Seaman et al. 1999).

We measured or calculated 14 structural features at each nest site. We used a clinometer to measure height of the nest, the nest tree, and adjacent forest. Height of the adjacent forest was determined by measuring the heights of the four nearest dominant trees within 100 m of the nest tree. We averaged these heights to estimate the adjacent forest height. We used a convex spherical densiometer (Lemmon 1957) to estimate cover. Within the nest tree, we estimated nest cover by averaging densiometer readings from two locations directly on top of the nest structure. From the ground, we estimated canopy cover by averaging densiometer readings from directly under the nest and at points 10 m in each cardinal direction from the point directly under the nest. We used a diameter tape to measure diameter at breast height (DBH) of the nest tree. We used a compass to determine the directional quadrant (northeast, northwest, southeast, southwest) of the tree in which the nest was located, relative to the main stem. At the nest, we measured the maximum and minimum widths of the nest structure, depth of the nest from top of rim to deepest point, and depth of cup from top of rim to deepest point. We recorded species of the nest tree. In addition, two variables were calculated, nest position and nest-tree dominance. Nest position was the nest height expressed as the percent of the nest-tree height. Nest-tree dominance is the nest-tree height divided by the adjacent forest height. Dominance values below one indicate the tree is shorter than the surrounding trees (i.e., subordinate), and values greater than one indicate the tree is taller than the surrounding trees (i.e., dominant).

We used the log-likelihood chi-square test (Manly et al 1993) to examine whether nests were uniformly distributed among quadrants. We used a *t*-test to compare vertical cover at the nest to ground-based cover in the nest-tree vicinity. We used the arcsine transformation (Sokal and Rohlf 1981) to transform cover percentages. We used a *t*-test to compare nest tree height with adjacent forest height. We transformed tree heights using the natural-log transformation because they were not normally distributed.

Table 1. Number of occupied nest areas, number of nest areas with pairs that produced young successfully, and number of young produced at Gray Hawk nests at the San Pedro National Conservation Area, Cochise County, AZ, 1995–97.

	1995	1996	1997	TOTAL
Occupied[a]	25	23	25	73
Successful[b]	14	15	19	48
Young produced[c]	28	29	39	96

[a] A nesting area at which two adult birds were located and observed exhibiting behaviors typical of nesting (e.g., vocalizations), regardless of whether a nest structure was located.
[b] A nesting area at which nestlings were present within 2 wk of normal fledging age, i.e., >28-d old.
[c] The number of young counted at successful nests (see Methods).

Table 2. Number of Gray Hawk nest areas at which pairs were successful according to number of years of the study during which they were successful at the San Pedro National Conservation Area, Cochise County, AZ, 1995–97. A nesting area was considered successful when nestlings were present within 2 wk of normal fledging age (>28-d old).

	SUCCESSFUL ALL SITES[a]	SUCCESSFUL 3-YR SITES[b]
All years	9	9
2 of 3 yr	7	6
1 of 3 yr	7	5
0 of 3 yr	4	1
Total	27	21

[a] The number of nest areas, out of all identified nesting areas, at which pairs were successful during 0, 1, 2, or 3 yr.
[b] The number of nest areas, out of the 21 areas at which pairs were present (i.e., occupied sites) during all 3 yr of the study, at which pairs were successful during 0, 1, 2, or 3 yr.

RESULTS

We identified 27 breeding territories that resulted in 73 nesting attempts during the 3 yr of this study (Table 1). Number of successful breeding pairs (log-likelihood $\chi^2_2 = 2.257$, $P = 0.3235$) did not differ among years, with a mean of 16 successful pairs per year (range = 14–19). Individual breeding sites exhibited variation in number of years occupied and successful (Table 2).

Productivity averaged 1.32 young per occupied site during the 3 yr of the study (range = 1.12–1.56). Number of young produced (Kruskal-Wallis, $\chi^2_2 = 2.3096$, $P = 0.3151$) did not differ among years. Number of young per successful site was 2.0 over the 3 yr (range = 1.93–2.05). Individual sites produced 0 to 8 young over the 3-yr period ($\bar{x} = 3.56$).

Gray Hawks used 52 nest structures during the 3 yr of the study, with a mean of 1.38 nests used per nesting area. Four nests (7.7%) were used during all 3 yr. Twelve nests (23.1%) were used during 2 yr. The remaining 36 nests (69.2%) were used only once. The breeding attempt at one nesting area failed prior to completion of a nest.

Breeding hawks at territories in which the pair failed during the previous year tended to use new nest structures the following year more often than hawks at sites in which the pair was successful the previous year (Fisher's exact test, $P = 0.0644$). We excluded territories that were unoccupied the following year from the above analysis.

We determined home ranges for 10 breeding males. Estimated home ranges were based on a mean of 52 locations (range = 36–65). Size of home ranges based on the AK method averaged 59.2 ha (range = 21.4–91.2 ha). Size of home ranges based on the MCP method averaged 90.3 ha (range = 47.6–179.5 ha).

Fifty of the 52 Gray Hawk nests we located were in cottonwoods. The remaining two nests, both located within the same nesting area, were in willow trees. Vertical cover over nests was significantly higher than vertical cover measured from the ground near the nest tree ($t_{48} = -2.863$, $P = 0.0062$; Table 3). Nest trees were significantly higher than the surrounding trees ($t_{50} = -3.012$, $P = 0.0041$).

DISCUSSION

The productivity we recorded (1.32 young/occupied site) is slightly higher than the 1.18 young/occupied site observed in Arizona from 1973–76 (Glinski 1988). However, the range of productivity during our study falls within that observed during the 1970s (0.71–1.67 young/occupied site; Glinski and Millsap 1987). Therefore, our data do not likely represent an increase in productivity of the Gray Hawk population in Arizona. The rate of productivity we observed is consistent with observed rates for other medium-sized raptors (Newton 1979).

Gray Hawks have small home ranges and adjacent nests may be in close proximity. The mean home range (90.3 ha; MCP method) is about half the 170 ha observed for males of the similar-sized Red-shouldered Hawk (*Buteo lineatus*) in California

Table 3. Summary statistics for 12 variables measured at Gray Hawk nest sites at San Pedro National Conservation Area, Cochise County, AZ, 1995–97. Some measurements could not be obtained at all nests.

FEATURE	$\bar{x}$	SE	N	95% CI	RANGE
Nest height (m)	19.2	0.80	26	[17.6, 20.9]	14.2–31.5
Tree height (m)	30.0	1.31	26	[27.3, 32.7]	23.0–45.0
Adjacent forest height (m)	25.0	1.17	26	[22.6, 27.4]	13–43.5
Nest position %[a]	64.9	2.01	26	[60.8, 69.1]	50.0–83.3
Dominance[b]	1.23	0.05	26	[1.12, 1.34]	0.90–1.96
Canopy cover (%)	86.8	1.92	26	[82.8, 90.7]	55–98
DBH (cm)	92.5	7.28	26	[77.5, 107.5]	48.5–181.0
Nest diameter (max cm)	50.7	1.82	26	[47.0, 54.4]	23–66
Nest diameter (min cm)	40.3	1.70	25	[36.8, 43.8]	18–53
Nest depth (cm)	26.4	1.41	26	[23.5, 29.3]	13–40
Cup depth (cm)	2.7	0.42	26	[1.8, 3.5]	0–7
Nest cover (%)	92.8	1.87	24	[88.9, 96.6]	63–100

[a] Vertical location of nest in tree (nest height × 100/nest tree height).

[b] Nest tree dominance (nest tree height/adjacent forest height).

(Bloom et al. 1993). It is possible that Gray Hawks have smaller breeding home ranges than any other North American buteonine raptor.

We found that Gray Hawks usually built nests in dominant cottonwoods. Nests were placed in the upper half of cottonwoods, usually away from the main stem of the tree. Gray Hawks are known to be associated with cottonwood forests and mesquite woodlands in the northern portion of their range (Glinski 1988). Mesquite woodlands have been assumed to function as the primary foraging areas, with cottonwood forests being used primarily for nesting (Stensrude 1965, Glinski 1988). Historically, Gray Hawks were reported to nest >9-m high in mesquites (Bent 1937). Few, if any, mesquite trees of this size remain in Arizona. Furthermore, few trees other than cottonwoods remaining along riparian areas in southern Arizona are this tall. Gray Hawks probably select the most dominant trees in an area for nesting, regardless of species. Eventually Gray Hawks may begin nesting in mesquite trees as these grow to heights that are suitable for nesting.

The number of breeding Gray Hawks has increased along the upper San Pedro River during the last 25 yr, and in Arizona as a whole. In the early–mid 1970s, statewide there were 39 known nesting areas, including some that were not producing young or were occupied by a single adult (Porter and White 1977). There are now over 80 known nesting areas (Glinski 1998). During this study (1995–97), 23–25 nest territories were occupied along this 64 km of river. Gray Hawks were first recorded nesting on the San Pedro River in 1964 (Glinski and Millsap 1987). In 1977, 16 sites were known along the entire river, 11 within our study area (Glinski and Millsap 1987). In 1985, 20 territories were known for the entire river, again with 11 nests within our study area (Glinski and Millsap 1987). The increasing number of breeding Gray Hawks along the San Pedro River probably was the result of an increase in habitat for this species in this area. Prior to 1900, vegetation along the river consisted of extensive areas of cienega, with some areas of cottonwood forest and mesquite. Woodcutting heavily impacted the cottonwood and mesquite forests during the late 1800s (Tellman et al. 1997). By 1920, mesquite had replaced most of the cienegas along the river (Tellman et al. 1997). The number of Gray Hawks has probably increased as areas of mesquite along the river have matured into extensive woodlands providing increased foraging habitat for nesting Gray Hawks.

However, continued growth of trees within mesquite woodlands, as well as presence of cottonwood forests along the San Pedro River depends on maintenance of the existing water table along the river (Tellman et al. 1997). Depletion of groundwater and human development already has resulted in the loss of much of the mesquite woodlands and cottonwood forests along the nearby Santa Cruz River (Tellman et al. 1997), with many areas that had significant numbers of Gray Hawks no longer providing habitat for this species. For example, Bendire (1882, 1892) described several

Gray Hawk nests along Rillito Creek in Tucson, an area that now both dewatered and urbanized, and reported that the Gray Hawk was considered common in the Tucson area. Swarth (1905) described several nests in the mesquite forest around the San Xavier mission south of Tucson that contained trees as high as 18 m. This forest no longer exists. Gray Hawks were absent from this area by 1948, when the Santa Cruz River was no longer a permanent stream in Arizona (Phillips et al. 1964). Historically, these woodlands were the center of the Gray Hawk population in Arizona (Glinski 1988). Maintenance of adequate levels of groundwater may be the most important requirement for ensuring long-term presence of breeding Gray Hawks along the San Pedro River, and in Arizona, by ensuring continued presence of the cottonwood and mesquite forests that provide habitat.

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